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BULLETIN NO. 331.

Soils and Fertilizer Experiments, Experiment Station Farm, Lexington.

By GEO. ROBERTS and E. J. KINNEY

INTRODUCTION

The work upon the outlying soil experiment fields was reported in Bulletin No. 322 (1931).^{*} The soils and fertilizer experiments on the Experiment Station farm at Lexington were not included in that bulletin because some of the results are a guide to practice on only the highly phosphatic soils of the Central Bluegrass region. However, some of them have a general application on all types of soil, both within and without the Bluegrass region.

What is commonly designated as the Central Bluegrass region is an area of about 1200 square miles, the center of which is near Lexington. It includes the counties of Bourbon, Fayette, Jessamine and Woodford and more or less of Boyle, Clark, Franklin, Garrard, Harrison, Lincoln, Madison, Mercer and Scott counties. The general opinion that the soils of this entire region are highly phosphatic and very much alike in other respects is erroneous; much variation occurs in them, even in the better parts of the area. For example, on the Experiment Station farm of 600 acres, there is a wide variation in the character of the soil. On one part of the farm the phosphorus content is 12,000 pounds in 2,000,000 pounds of surface soil (an acre to the depth of about 7 inches), while 300 feet away it is 7500 pounds, and within three quarters of a mile it is 2100 pounds. Within Fayette County, soils are found with a

^{*}Bulletin No. 322 contains recommendations on soil management and fertilizer practices applicable to various regions of the state. It will be sent to residents of Kentucky free upon application.

still lower phosphorus content. Because of this wide variation in soil characteristics, the best use of fertilizers can, in many cases, be determined only by tests on individual farms. Suggestions for making such tests are given in the latter part of this bulletin.

General Plan of the Experiments. Where a rotation of crops is used in an experiment, provision is made for each crop to be grown each year, unless otherwise noted. For example, on the Lexington experiment field, the fifteen plot treatments shown in the first column of Table 1 are used on four different series of plots to accommodate the four-year rotation of corn, soybeans, wheat and clover. If a three-year rotation had been used, three series of plots would have been required.

The plots used in the experiments range in size from $1/40$ to $1/12$ of an acre; the majority contain $1/20$ acre.

The Use of Check Plots. No tract of land, however uniform it may appear to the eye, is equally productive in all portions. This is true of even small tracts, as for example, a kitchen garden, some parts of which are nearly always better than others. It is evident, therefore, that in plotting land for soil experiments there will be more or less difference in productivity among the different plots, especially those most widely separated. Obviously, therefore, to obtain reliable information regarding the relative effects of various treatments, untreated plots or plots having a uniform treatment must be distributed at frequent intervals thruout a series of plots, to serve as check plots. In the older experiments an insufficient number of check plots was used, because their importance was not fully appreciated at the time the experiments were started. If the difference in yield between two treated plots, or between a treated plot and a check plot, is not greater than the difference in the yields of the check plots between which the treated plots lie, the difference should not be considered significant.*

Basis of Calculating Crop Yields. Crop yields are reported on the basis of field-cured weights, except that in 1928, 1929 and 1931 the yields of corn were calculated on the basis of the

*For further discussion of the use of check plots, see Kentucky Experiment Station Bulletin 322, pages 356-359.

weight of shelled corn after air-drying thru the winter. Corn husked from the shock in November loses, on the average, about 12 percent of moisture by March. Facilities and help were not available for making accurate moisture determinations on crops from the very large number of plots involved in the work of the department. Efforts were always made to have the crops as well field-cured when weighed as conditions would permit. Soybeans frequently are harvested late, when weather for curing is unfavorable. Also, soybeans cure more slowly than grass and clover; consequently soybean hay contained more moisture when weights were taken than other hay. However, the ratios of yields of plots of different treatments are not greatly affected by using field-cured weights.

THE LEXINGTON SOIL EXPERIMENT FIELD

This field was established to represent the highly phosphatic soils of the Central Bluegrass region. These soils are found in the Trenton limestone formation occurring principally in Fayette, Jessamine, Boyle, Mercer, Woodford, Scott, and Bourbon counties, with smaller areas in contiguous counties. However, no county is entirely covered by the formation. As already stated, it is characteristic of the area that the phosphorus content of the soils may vary widely within a short distance. Even on the Lexington soil experiment field there is a wide variation within its area of eight acres, as is shown by analyses of composite samples of soil from Plots No. 3 and Plots No. 13 given below. The figures represent pounds of the elements in 2,000,000 pounds of surface soil (weight of an acre to the depth of about 7 inches):

	Plots 3	Plots 13
Total nitrogen	4,520	4,400
Total phosphorus	12,400	7,640
Total potassium	27,000	29,000

The acidity of the soil of this field is not high, the pH value being approximately 5.4. The lime requirement, determined by the Hopkins method, is nothing, while by the Veitch

method it is about 3000 pounds (CaO) in 2,000,000 pounds of soil.

The field used for these experiments was occupied by blue-grass sod for a number of years prior to 1900, when it was plowed and used for miscellaneous cropping until the experiments were started in 1911. So far as can be ascertained, no lime or manure was used on any part of the field prior to this experiment. Some fertilizer tests were made on a small part of it from 1900-1903, but were of such a nature that they did not affect the uniformity of the land for use in these experiments. The experiments on this field consist of fertilizer and liming tests and a comparison of crop rotations and continuous corn culture.

Fertilizer and Liming Tests in the Four-Year Rotation. This rotation was corn, soybeans, wheat and clover, with a cover crop between corn and soybeans. Cowpeas, soybeans and crimson clover were tried as catch crops in corn for a few years, but they made such poor growth that rye was used after 1918.

Beginning with the crops of 1915, the cornstalks were left on the ground and the wheat straw and soybean straw were returned to the clover sod to be broken for corn, except on Plots 5 and 10. These residues were applied for three rounds of the rotation, after which their use was discontinued. They were applied in the fall seven times in twelve, and the land was fall-plowed four in twelve times. The treatment of Plot 15 was modified during the course of the experiment, as will be indicated later. The average annual weight of soybean straw and wheat straw returned was approximately 2500 pounds per acre of each.

Limestone and fertilizers were applied only on the corn ground. The rates were as follows:

Limestone: 4 tons per acre, 1911-15; 2 tons per acre, 1916-18; 1 ton per acre, 1919-22; an average total application of 7.5 tons per acre in 21 years.*

*The amount of limestone used was in excess of the needs of this soil and of most soils in Kentucky. At the time this experiment was begun, little was known of the amount of lime needed on Kentucky soils.

Superphosphate (16 percent): 800 pounds per acre 1911-22; 400 pounds per acre 1923-31.

Muriate of potash, or its potash equivalent: 500 pounds per acre 1911-15; 400 pounds per acre 1916-22; 200 pounds per acre 1923-31.

Since no plots received treatment until planted to corn, it is obvious that in beginning the experiment the other crops in the rotation were not influenced by the treatment until they appeared on the plots where corn was grown the first year; consequently they were not harvested by plots previously.

Corn was a failure in 1930 on account of drouth. Soybeans were harvested for seed to 1927, inclusive; after that, for hay. Wheat failed in 1924 and 1928 due to winterkilling. There were four clover failures—1916, 1917, 1921 and 1931, the latter due to drouth. Except for 1921, soybeans were grown as a substitute. In 1924 a mixture of clover and alfalfa was sown instead of clover. The results were reported in Bulletin No. 272. Six crops of soybeans were harvested for hay. Soybeans, wheat and clover were not harvested by plots until they appeared in the rotation following the first corn crop—that is, in 1912, 1913 and 1914, respectively. Table 1 gives the plot treatments and crop yields in the four-year rotation.

TABLE 1. CROP YIELDS PER ACRE, FOUR-YEAR ROTATION, LEXINGTON SOIL EXPERIMENT FIELD.

Plot No.	Treatment*	Corn, Bus. Ave. 20 Crops	Soybeans, Bus., Ave. 16 Crops	Wheat, Bus., Ave. 17 Crops,	Clover Hay Lbs., Ave. 13 Crops.	Soybean Hay, Lbs. Ave. 6 Crops
1	RP	47.1	19.3	26.6	4062	4368
2	RK	47.1	19.8	27.1	4392	4359
3	R	50.7	19.3	27.1	4004	4201
4	RPK	50.2	19.6	26.9	4196	4384
5	PK	52.8	19.0	26.6	4121	4270
6	RLP	52.6	18.8	27.2	3943	4167
7	RLK	57.3	19.6	27.3	4023	4440
8	RL	56.8	18.3	27.6	3339	4227
9	RLPK	57.7	20.3	28.8	4201	4453
10	None	57.1	17.9	25.8	3329	4004
11	RP	54.4	18.3	26.7	3489	3890
12	RK	55.1	18.7	26.7	3866	4185
13	R	56.0	18.1	27.1	3700	3896
14	RPK	55.7	18.8	26.6	4278	4365
15	RLPK	See page 226 for discussion of this plot				

Average of Duplicate Treatments

1,11	RP	50.8	18.8	26.7	3776	4129
2,12	RK	51.1	19.3	26.9	4129	4272
3,13	R	53.4	18.7	27.1	3852	4049
4,14	RPK	53.0	19.2	26.8	4237	4375

*L = limestone; P = superphosphate; K = potash; R = crop residue.

Neither limestone nor any of the fertilizers produced profitable increases in any of the regular crops in this rotation. However, the results should not be construed as proving that these treatments would be ineffective on all the soils of the Central Bluegrass region, because, as stated in the introduction, several kinds of soil occur in this area, some of which are deficient in phosphorus. On this field, when alfalfa was substituted for clover in 1924 (see Bulletin 272, page 291), considerable increases were produced by both limestone and potash. On another field on the Experiment Station farm, tobacco also responded to potash, as will be noted in the report of the tobacco fertilizer tests (page 248).

It will be observed, by comparing Plot 4 with Plot 5 and Plot 10 with Plot 13, that crop residues apparently have had practically no effect on crop yields, except possibly on clover. A study of the crop yields by rotation periods shows more clearly their effect than do the averages of crops for the entire period. As stated, no residues were returned until 1916, and their use was discontinued with the crops of 1927. Table 2 gives the average yields of crops by rotation periods, beginning with 1912 for corn, and one, two and three years later for the other crops. There was no clover in the fifth period. In the first period the crops were not affected by residues. For the second, third and fourth periods the corn followed immediately the application of soybean straw and wheat straw, and soybeans followed immediately the plowing under of cornstalks and also received the residual effect of the residues applied for corn, while wheat and clover also received the residual effect. Where there was a crop failure in a period, it is indicated, and the average yield for the same plots for the preceding rotation is given in (.....) for comparison. In the fifth rotation period the corn is four years removed from the last application of residues, the soybeans five years, and the wheat six years.

TABLE 2. EFFECT OF CROP RESIDUES ON CROP YIELDS. AVERAGE YIELDS OF CROPS BY ROTATION PERIODS.

Rotation Period*	(1) Corn, Bus.				(2) Soybeans, Bus.				(3) Wheat, Bus.				(4) Clover, Lbs.			
	Plot 4 RPK	Plot 5 PK	Plot 13 R	Plot 10 O	Plot 4 RPK	Plot 5 PK	Plot 13 R	Plot 10 O	Plot 4 RPK	Plot 5 PK	Plot 13 R	Plot 10 O	Plot 4 RPK	Plot 5 PK	Plot 13 R	Plot 10 O
First	46.3	50.4	60.1	59.4	19.9	18.6	20.0	21.1	29.8	29.6	29.7	28.8	4638	4410	4488	4299
Second	50.0	53.7	57.2	58.9	16.8	16.8	15.6	16.0	23.1	21.4	21.9	20.0	4808 (5004)	4648 (4900)	4304 (5084)	4136 (4988)
Third	41.2	44.7	47.2	51.3	20.5	18.9	15.8	14.7	23.3 (26.9)	23.3 (24.7)	24.0 (21.8)	23.4 (23.6)	4425	4655	3336	2520
Fourth	58.1	64.7	59.7	62.4	19.9 (22.8)	20.0 (20.7)	18.4 (17.4)	16.0 (15.4)	33.7 (32.7)	33.2 (32.6)	34.9 (35.3)	33.1 (31.7)	3350	3112	2994	2568
Fifth	64.2 (58.4)	59.7 (61.9)	62.2 (59.6)	61.2 (58.8)	4201	4262	3693	4208	27.8 (32.7)	27.8 (32.6)	28.4 (35.3)	25.3 (31.7)	—	—	—	—

(1) Average of three crops in fifth rotation period. Failure in 1930.

(2) Fourth rotation period, only three crops of soybean seed; fifth period, average of three crops of soybean hay (ends in 1932).

(3) Average of three crops of wheat each in the third and fourth periods due to failure; two crops in the fifth period (ends in 1933).

(4) Average of three crops of clover in second rotation period. Soybeans and mixed clover and alfalfa used when clover failed in other periods.

* The figures in () are averages for the same plots of the preceding period as those of the period with which they occur. These comparisons are made necessary by crop failures.

Plot 15 was a duplicate, in treatment, of Plot 9 to 1923, inclusive, both having received residues from 1916 to 1923. From 1924 to 1927, inclusive, manure was applied to corn on Plot 15, in amounts equal to the weights of the crops removed from this set of plots the preceding year, while residues were continued on Plot 9. It had been observed that crop residues were not increasing yields, and it was desired to test the effect of manure in comparison with residues. Table 3 gives a comparison of yields of corn on Plots 9 and 15.

TABLE 3. CORN YIELDS ON PLOT 9, WITH CROP RESIDUES, AND ON PLOT 15, WITH MANURE.

Period	Plot 9	Plot 15
1912-1915 No residues _____	60.8	56.2
1916-1923 Residues _____	53.5	50.3
1924-1927 Res. on 9, M. on 15 _____	63.4	66.8

For the eight-year period, 1916-23, when crop residues were applied to the corn on Plots 9 and 15, the average yield of corn was 3.2 bushels higher on Plot 9 than on Plot 15. For the four years, 1924-27, when manure was used on Plot 15 and crop residues on Plot 9, the yield of corn was 3.4 bushels higher on Plot 15. Apparently, manure changed the yield on Plot 15 from a lag of 3.2 bushels behind Plot 9 to a gain of 3.4 bushels above it, or an increase of about 7 bushels per acre, whereas crop residues failed to increase the yield of corn on other plots (see Table 2). The manure did not increase the yield of soybeans and wheat. The yield of clover was increased about 650 pounds per acre.

The question naturally arises as to why crop residues failed to increase yields. One reason may be in the nature of the residues. Cornstalks and wheat straw have a wide carbon-nitrogen ratio—that is, the percentage of nitrogen is small, compared with the percentage of carbon. The carbon-nitrogen ratio of bean straw is narrower, but the mixture of all these residues has a fairly wide ratio. It has been discovered by

various research workers that the bacteria in the soil that cause the decomposition of organic matter require considerable available nitrogen for their activities. If the organic matter (crop residues in this case) does not furnish sufficient available nitrogen, the bacteria draw upon the supply in the soil and thus compete with the crop. As organic matter decomposes, the carbon-nitrogen ratio narrows to a point at which the nitrogen released by further decomposition more than meets the needs of the bacteria and is therefore available to plants. This process of decomposition explains, in many cases, the common observation of farmers that turning under wheat straw or rye near maturity frequently reduces the yield of the following crop.

Another possible reason for the ineffectiveness of residues under the conditions of this experiment may be that the soil contained enough nitrogen for crop needs. It contained about 4500 pounds (see page 221) in 2,000,000 pounds of soil, at the beginning of the experiment. Nitrogen accumulated from the clover crop and possibly from non-symbiotic nitrogen fixation may have been sufficient for corn crops as large as climatic conditions in this region permit. It is not likely that the yield of corn can be kept much above 60 bushels per acre, on the average, because of lack of moisture.

That the nitrogen supply is probably sufficient is shown by a test made in 1929 (four years removed from the last application of residues) when about 150 pounds of nitrate of soda per acre was used in the hill on one half of each plot of corn. The nitrate was applied with a fertilizer attachment of a corn planter which split the application and placed it on each side of the hill. The rate was higher than was intended, because of inability accurately to regulate the drill, but no signs of injury to the plants were apparent. The average yield for the nitrated half of all plots was 68.2 bushels per acre, and for the other half, 67.3 bushels. On Plots 5 and 10, to which no residues were returned, the average increase for nitrate of soda was 1.3 bushels per acre. Probably on soils more deficient in nitrogen and potash, crop residues would be effective.

In considering these results, the question occurs as to the economic limit of nitrogen maintenance. The average yield of corn in the clover rotations of the rotation experiments (see page 237) for 10 years is 58.3 bushels. This soil had a nitrogen content of approximately 3,200 pounds in 2,000,000 pounds of soil when the experiment was begun. The yield of corn on Plots 3 and 13 of the Lexington soil experiment field for the same period was 53.5 bushels. The average nitrogen content of these two plots was 4460 pounds when the work was begun in 1911, and a large amount of residues has been returned to them since.

The Three-Year Rotation. Beginning at the same time as the four-year rotation, a three-year rotation of corn, wheat and clover was used on two sets of plots (Nos. 16 and 17) adjacent to the plots used in the four-year rotation. Limestone was used on one set of plots (No. 17), at the same time and at the same rate as in the four-year rotation. The corn was cut, but after wheat was sown the cornstalks were returned. The wheat straw was applied to the corn land as in the four-year rotation. The crop yields of this rotation are given in Table 4.

TABLE 4. CROP YIELDS PER ACRE, THREE-YEAR ROTATION, LEXINGTON SOIL EXPERIMENT FIELD.

Plot No.	Treatment	Corn, Bus. Ave. 20 Crops	Wheat, Bus. Ave. 17 Crops	Clover Hay, Lbs. Ave. 13 Crops
16	R	57.2	21.6	3888
17	RL	57.0	21.9	4174

Plots 16 and 17 of the three-year rotation are to be compared with Plots 13 and 8, respectively, of the four-year rotation. There is no significant difference in yields of corn and clover in the two systems. There is a difference of 5.6 bushels of wheat in favor of the four-year rotation. Whether this difference in yield is due to the fertility effects of the rotations as a whole or to the effect of the preceding crop cannot be determined from these experiments. The rotation experiments reported on page 237 throw some light on the question.

Continuous Corn Culture. Corn was grown continuously on two plots on this field from 1911 to 1922. On one plot a legume catch crop of some kind was planted at the last cultivation, but it generally failed or made very poor growth. The stalks were left on both plots from 1915 to 1923, and a rye cover crop was used.

The average yield of corn on these two plots for the first three years was 35.2 bushels per acre, as compared with 44.9 bushels on nearby unlimed plots of the three-year rotation. For the 12 years the average was 29.4 bushels without the legume catch crop, and 32.0 bushels with the legume catch crop. The yield of corn on the unlimed plots in the three-year rotation, for the same period, was 52.9 bushels.

In 1923 the plot on which a legume catch crop had been planted in the corn was limed, and corn was again grown on both plots, followed by wheat and clover in regular rotation since.

Two clover crops have been grown, which averaged 2971 pounds without lime and 3439 pounds with lime. In the original three-year rotation the yields, with similar treatments, were 3072 pounds and 3958 pounds.

Two crops of wheat averaged 17.3 bushels and 18.5 bushels, as compared with 18.2 bushels and 17.9 bushels in the original three-year rotation for the same years.

Two crops of corn following clover averaged 48.6 bushels and 49.6 bushels, as compared with 67.6 bushels and 68.4 bushels in the original three-year rotation for the same years.

While there is rapid recovery of productiveness, it is evident that continuous corn culture has a very detrimental effect on the yield of corn.

The plans on this field were changed following the harvests of 1931. The four-year rotation was changed to corn, wheat and alfalfa for two years. All unlimed plots were limed. The original fertilizer treatments will be continued. Manure will be used on the corn land. The three-year rotation and the plots formerly used for continuous corn culture were combined for a four-year rotation of barley followed by three years of alfalfa, with fertilizer treatments. The purpose is to find a rotation

that produces a maximum of feed crops with a minimum of tillage and seeding expense. The former rotation, which included soybeans, requires a cover crop and too much tillage and seeding expense.

THE RENEWED FERTILIZER EXPERIMENTS

Beginning in 1888 and continuing until 1898, the Experiment Station conducted field tests with fertilizers for a number of crops, including corn, wheat, tobacco and potatoes. The tests were made in continuous culture (except tobacco), without catch crops, winter cover crops or the return of manure. The soil is described in the reports of the experiments as having a "light-colored clay subsoil so retentive as to make the soil deficient in natural drainage. The land is worn, having been in cultivation for many years."

In these tests, phosphate and nitrogen fertilizers produced no increased yields of corn of significance, while potash produced a very large increase. Typical of these results are the following average yields of corn crops from 1889 to 1894 (except 1893—records lost in fire):

No treatment	32 bushels
Phosphorus and nitrogen	31 bushels
Phosphorus and potash	56 bushels
Potash and nitrogen	64 bushels
Phosphorus, potash and nitrogen	62 bushels
Potash	56 bushels

The fertilizer materials were used at the following rates per acre each year:

Superphosphate (equivalent 16 percent grade)	350 lbs. (approximate)
Muriate of potash	160 lbs.
Nitrate of soda	160 lbs.

In 1898 the Experiment Station purchased land adjoining that on which these tests were made, but of a different type, being much better drained and containing much more phosphorus and a little more potassium. Fertilizer tests on this land failed to show any significant response to potash under the conditions of the test (see page 223). The plots on which

the old fertilizer tests were made were seeded to bluegrass soon after 1898.

In 1914, at the suggestion of Dr. A. M. Peter, it was decided to renew some of the old experiments. The plots that had been used for the tests with corn were not available, but two series of plots that had been used for wheat and potatoes at the same time were available. These were near the corn plots, and the same plan of fertilization had been used as on the corn plots. It should be stated here that in the old tests fertilizers had very little effect on the yield of wheat, but produced results on potatoes similar to those on corn. While the land was in pasture it was manured occasionally, but the amount was not recorded; however, it was not excessive. Analysis of soil from the check plots, in 1914, gave the following results, stated as pounds in 2,000,000 pounds of soil:

	Series C	Series D
Total nitrogen	4,480	4,300
Total phosphorus	6,540	4,900
Total potassium	26,300	23,300

The nitrogen content of the soil of these two series of plots was only slightly less than in the soil of the Lexington soil experiment field when the experiments were started on the latter.

In 1914 both series of plots were cultivated in corn without any fertilization, to determine whether any residual effect of the former use of potash remained, and also to compare their productiveness. The yields were low because of deficient rainfall. It will be noted that the average yields of the two sets of plots are identical. The results of this test are given in Table 5.

In 1915 fertilizers were applied to the plots of both series according to the old plan of treatment, but not at the same rate. Two hundred pounds of superphosphate, 80 pounds of muriate of potash, and 50 pounds each of nitrate of soda and dried blood per acre were applied. On one set (Series C) a rotation of corn and soybeans was followed until 1927. The cornstalks were left on the ground, the soybean straw was returned, and a rye cover crop was used each year. On the other set (Series D) corn was grown continuously for the same period. The

entire crop was removed, and no cover crop used. From 1916 to 1927, fertilizers were applied at the following rates on each crop on both series.

TABLE 5. YIELDS OF CORN PER ACRE ON SERIES C AND D, 1914.

Series C			Series D		
Plot No.	Former Treatment	Yield Bushels	Plot No.	Former Treatment	Yield Bushels
1	O	38.9	1	O	43.4
2	P	41.0	2	N	44.3
3	O	49.4	3	P	44.7
4	K	45.4	4	K	41.7
5	N	43.4	5	O	39.3
6	O	39.3	6	PN	43.4
7	PK	41.9	7	KN	45.4
8	PN	44.7	8	PK	49.4
9	KN	44.3	9	PKN	41.0
10	PKN	43.4	10	O	38.9
	Average	43.2		Average	43.2

O = no treatment; P = superphosphate; K = muriate of potash; N = nitrogen from nitrate of soda or dried blood.

The cornstalks were left on Series C, and a rye cover crop was sown. On Series D, the cornstalks were removed and no cover crop was used, in order to conform to the old experiments.

Superphosphate	140 lbs.*
Nitrate of soda	160 lbs.
Muriate of potash	160 lbs.

All fertilizers were applied broadcast, as in the old experiments, except that from 1923 to 1927 the nitrate of soda was put around the hill for corn, after it was planted. The results of the two experiments are given in Tables 6 and 7.

In 1928 both series of plots were seeded to oats, without further addition of fertilizers. On one half of each plot, as much hydrated lime was drilled with the oats as the fertilizer attachment would deliver. The amount was approximately 425 pounds per acre. On the entire area a mixture of 14 pounds of bluegrass, 2 pounds of timothy, and 3 pounds of red clover per acre was sown. On one half of both the limed and unlimed

* Thru a misunderstanding caused by a change in the grade of superphosphate used in the old experiments, an error was made in applying 140 pounds of superphosphate in the renewed tests, instead of the amount used in the old tests.

TABLE 6. AVERAGE YIELDS OF CROPS IN ROTATION OF CORN AND SOYBEANS IN RENEWED EXPERIMENTS (SERIES C).

Plot No.	Treatment*	Corn, Bus. Ave. 7 Crops 1915-1927	Corn, Bus. 1931	Soybeans, Bus. Ave. 5 Crops 1916-1926
1	O	53.3	51.0	13.8
2	P	54.3	50.7	13.8
3	O	53.4	51.2	13.6
4	K	52.4	57.7	13.4
5	N	56.0	58.3	13.4
6	O	52.6	46.3	13.4
7	PK	54.1	62.2	14.8
8	PN	57.9	59.1	16.1
9	KN	57.2	59.1	15.5
10	PKN	55.3	61.4	15.0
Average		54.7	55.7	

TABLE 7. YIELD OF CORN IN CONTINUOUS CULTURE, RENEWED EXPERIMENTS (SERIES D).

Plot No.	Treatment*	Corn, Bus. Ave. 13 Crops 1915-1927	Corn, Bus. 1931	Ave. for Same Years Corn was Grown in Rotation with Beans
1	O	36.8	36.4	39.4
2	N	43.6	30.2	47.5
3	P	36.3	37.5	38.5
4	K	34.4	44.2	36.3
5	O	34.2	39.7	35.7
6	PN	42.2	44.7	45.6
7	NK	45.8	53.8	49.4
8	PK	41.1	53.0	45.1
9	PKN	45.5	54.6	49.6
10	O	34.0	43.8	37.3
Average			43.8	42.4

*O = no treatment; P = superphosphate; K = potash; N = nitrate of soda.

areas 10 pounds per acre of sweet clover were sown. The oats on Series C yielded 47 bushels of grain and 1276 pounds of straw per acre, while on Series D the yields were 33 bushels of grain and 1114 pounds of straw. The grass mixture was harvested in 1929, but the weights were lost. There was a good stand of grass and clover on both series, and both made good yields. The growth appeared heavier on the limed half of the plots.

In 1930 both series were planted to corn. The rate and method of application of fertilizers were changed. For plots

receiving a "complete" fertilizer, 250 pounds per acre of a 4-10-6 analysis were used. Where partial analyses were called for, as much of each element was used to the acre as was contained in 250 pounds of complete fertilizer. The nitrogen was derived equally from nitrate of soda and sulfate of ammonia. The crop of 1930 was a total failure as a grain crop, on account of drouth. Rye was used as a cover crop on both series, and corn was grown again in 1931 and fertilized in the same way. The results are given in Tables 6 and 7.

As already stated, the average yield of corn for the ten plots of each series was identical in 1914. The cornstalks were left on Series C and a rye cover crop was sown. The entire crop was removed from Series D, and no cover crop was used. Both series were planted to corn in 1915 and fertilized as previously stated. The average yield for Series C was 77.4 bushels, and for Series D, 73.7 bushels an acre, a difference of 3.7 bushels. For the alternate years from 1915 to 1927 (when corn was grown in rotation on Series C), the average yield of corn on Series C was 54.7 bushels per acre, and on Series D, 42.4 bushels, a difference of 12.3 bushels per acre.

By any comparisons that can be made, the effect of superphosphate in the fertilizer is practically negligible in both tests, as would be expected on a soil containing as much phosphorus as these soils contain. For the period 1915-1927, nitrate of soda produced 3.3 bushels increase in corn on Series C, and 8.2 on Series D for the same years. Potash produced no increase on Series C and an average of 3.3 bushels on Series D for the same years. These increases for nitrogen and potassium are in each case the average of all comparisons that can be made to determine the effect of the element under consideration. When the effect of an element is determined by comparing the full treatment with the treatment that lacks the element under consideration (as, for example, PKN-KN to get the effect of phosphorus), it is found that phosphorus has had no effect; that nitrogen increased the yield of corn 1.2 bushels on Series C and 4.5 bushels on Series D for comparable years; that potash did not increase the yield on Series C and increased it 4.0 bushels on Series D for comparable years. On this basis of comparison,

potash and nitrogen (PKN-P) increased the yield of corn 1 bushel on Series C and 11.1 bushels for comparable years on Series D. When all the crops are taken into consideration on Series D, the effect of phosphorus is practically negligible, while the combination of nitrogen and potash produced an increase of 9.2 bushels per acre.

While there is a decided tendency toward a potash deficiency in the continuous corn series, it is not nearly so great as in the earlier experiments. The fact that a different series of plots was used may partially account for the difference, while the tile drainage and the intervening period of grass may have had considerable influence.

Previously it was stated that nitrate of soda was placed around the corn hills, beginning with 1923, whereas it had been applied broadcast before that time. The average increase for nitrate of soda on Series C, including all plots receiving it, was nothing for the years 1917-19-21, while for 1923-25-27 it was 7 bushels per acre. On Series D for 1918-22 the increase for nitrate of soda was 2.9 bushels per acre, while for 1923-27 it was 14.3 bushels per acre.

That the hill application was more effective than the broadcast application is shown by the fact that the corn yields were greater in the second period on the check plots of Series C than in the first period. In other words, it was not a greater nitrogen deficiency in the second period that accounted entirely for a greater response to nitrogen. The fact that the yield of corn on the check plots in Series D was less in the second period than in the first indicates that a greater deficiency of nitrogen during the second period was responsible for part of the greater response to this element.

In 1931, when all the fertilizers were put in the hill, they seem to have been much more effective than in the previous years when used broadcast. This is true for both series of plots. It is also worthy of note that after both series were in grass for two years, the yield of corn for 1931 averaged 12 bushels higher on Series C than on Series D. The results show the very great superiority of the soil management used in Series C as compared with continuous corn culture in Series D.

Unfortunately, there is no way of determining how much of the advantage was due to rotation and how much to residues. Since the residue plowed under for corn was soybean straw, it may be assumed that it was effective.

ROTATION EXPERIMENTS

In 1920 rotation experiments were begun on the Experiment Station farm, the objects of which were (1) to compare the effect of clover, soybeans and orchard grass on productivity and (2) to determine the effect on wheat of corn, tobacco and soybeans as preceding crops. The rotations employed were:

1. Corn, wheat, clover.
2. Corn, wheat, orchard grass.
3. Tobacco, wheat, clover.
4. Corn, wheat, soybeans (in 28-inch rows; drilled solid beginning with 1928).
5. Corn, soybeans (in 28-inch rows; drilled solid beginning with 1928), wheat.
6. Corn, soybeans (drilled solid), wheat. (Beans cut for hay till 1927, inclusive; afterwards threshed and straw returned for corn.)
7. Corn, wheat, clover.

All crops in the experiments were removed except what growth the clover and orchard grass made the year of seeding and the growth following harvest the second year. The clover seeding of 1925 failed and was reseeded the following spring. Clover and orchard grass seedings failed in 1927 and in 1930 and were reseeded the following springs. These seedings did not make enough growth for harvest. A cover crop of winter grain was used after wheat and soybeans in Rotation No. 4, and after corn and wheat in Nos. 5 and 6. No manure or fertilizers were used. The plots were all limed at the rate of 2 tons per acre, in 1927.

The land was in soybeans in 1918, wheat in 1919, and clover in 1920. In the spring of 1920 the first series of plots was plowed and planted to corn and tobacco, to start the rotation, but these crops were not made a part of the record. The

second series of plots was put in corn in 1921, following clover harvested in 1920. The corn yields of this year are of no value in comparing rotations. However, they have some value in showing the relative productivity of the plots occupied by the various rotations. After clover harvest in 1920, Series 300 was plowed. The appropriate plots were seeded to clover, orchard grass and wheat to complete the rotations.

The yields of crops in these rotations are given in Table 8.

TABLE 8. YIELDS OF CROPS IN ROTATION.

Corn, bushels; tobacco, pounds, per acre.

Year	Rot. 1 C-W-Cl	Rot. 2 C-W-OG	Rot. 3 Tob-W-Cl	Rot. 4 C-W-SB	Rot. 5 C-SB-W	Rot. 6 C-SB-W	Rot. 7 C-W-Cl
1921	29.1	31.1	2095	41.7	39.7	36.0	28.6
1922	48.6	45.1	1160	49.1	48.9	44.6	39.7
1923	73.4	58.6	1175	68.6	49.1	56.3	74.3
Ave. 1921-23	50.4	44.9	1477	53.1	45.9	45.6	47.6
1924	68.7	61.7	1060	70.0	53.7	52.0	58.0
1925	60.0	58.9	1040	59.1	47.4	49.1	48.0
1926	70.9	63.6	1015	71.7	55.5	61.4	73.1
Ave. 1924-26	66.5	63.1	1038	66.9	52.2	54.2	59.7
1927	62.3	59.1	650	34.6	31.7	35.9	65.8
1928	77.5	65.3	1275	57.7	45.8	55.7	80.2
1929	40.0	40.7	650	42.6	33.9	41.0	40.5
Ave. 1927-29	59.9	55.0	858	45.0	37.1	44.2	62.2
1931*	66.7	62.8	1360	50.9	44.7	48.7	60.0
Ave. 10 Crops	59.7	55.2	1148	54.6	45.0	48.1	56.8

*The corn crop of 1930 was a failure on account of drouth.

TABLE 8. YIELD OF CROPS IN ROTATION—Continued.

Wheat, Bushels per Acre

Year	Rot. 1 C-W-Cl	Rot. 2 C-W-OG	Rot. 3 Tob-W-Cl	Rot. 4 C-W-SB	Rot. 5 C-SB-W	Rot. 6 C-SB-W	Rot. 7 C-W-Cl
1921	22.3	24.0	23.5	22.8	20.3	17.3	26.5
1922	15.3	15.7	14.0	16.3	17.7	21.3	15.0
1923	23.7	23.3	25.3	19.7	20.7	17.3	24.7
Ave. 1921-23	20.4	21.0	20.9	19.6	19.6	18.6	22.1
1924	8.7	6.0	15.0	11.3	16.6	18.0	10.0
1925	23.3	21.7	32.3	22.7	19.3	21.0	24.0
1926	34.3	29.0	45.7	25.0	36.3	31.7	36.7
Ave. 1924-26	22.1	18.9	31.0	19.7	24.1	23.6	23.6
1927	22.5	16.9	24.9	16.5	21.3	22.3	18.3
1929**	26.7	22.0	32.7	22.0	27.3	28.0	27.3
1930	16.0	13.0	23.0	14.7	18.0	16.7	14.7
1931	41.8	42.0	47.0	40.3	31.7	34.0	41.3
Ave. 1929-31	28.2	25.7	34.2	25.7	25.7	26.2	27.8
Ave. 10 Crops	23.5	21.4	28.3	21.1	22.9	22.8	23.9

**Wheat failed in 1928.

It is very evident from these experiments that the residual effect of soybeans on productivity is decidedly inferior to that of clover, as measured by yields of corn and wheat. The average yield of corn was 2.7 bushels greater in Rotation No. 4 the first three years than in Rotation No. 1, but was 14.9 bushels lower in the average of the last three years. The yield of wheat was 2.4 bushels less in Rotation No. 4 than in No. 1, altho soybeans are generally supposed to be a more favorable crop than corn to precede wheat.

TABLE 8. YIELD OF CROPS IN ROTATION—Continued.
Hay, Pounds per Acre

Year	Rot. 1 C-W-Cl	Rot. 2 C-W-OG	Rot. 3 Tob-W-Cl	Rot. 4 C-W-SB	Rot. 5 C-SB-W	Rot. 6 C-SB-W	Rot. 7 C-W-Cl
1921	2620	2800	1960	5200†	3800†	2840†	3480
1922	4300	2200	5000	3700	3240	2640	4340
1923	4000	1500	3160	5100	5000	6200	1860
1924	4340	1700	3700	4800	4600	4900	5780
1925	2860	1100	3600	3240	2800	3220	2740
Ave. 1921-25	3624	1860	3484	4408	3888	3960	3640
1926	—	—	—	4000	3960	4900	—
1927	5440	2100	4440	5200	4600	2900	4280
Ave. 1921-27	—	—	—	4463	4000	3943	—
1928	—	—	—	6320	6120	18.7 bu.	—
1929	4095	2100	3731	4816	3650	10.5 bu.	4095
1930	840	160	660	1428	1288	—††	760
1931	—	—	—	3800	3300	13.0	—
Ave. 11 Years	2590	1242	2386	4328	3851	—	2485

‡Soybeans planted in 28-inch rows, 1921-27; drilled solid thereafter

†Soybeans drilled solid and harvested for hay, 1921-27; harvested for seed thereafter.

††Soybeans failed to mature seed on account of drouth.

There were 3 clover failures in 11 years in each of the rotations including clover, whereas there were no soybean failures. The 8 clover crops made a total of 14.2 tons of hay per acre in Rotation No. 1, whereas the 11 soybean crops in Rotation No. 4 made a total of 23.8 tons of hay per acre. The weights are for field-cured hay, and since soybean hay generally contains more moisture when taken from the field than clover hay, the difference is not quite so great as appears. If these crops had been fed and the manure had been returned to the

soil, the soybeans might have maintained productiveness as well as clover. However, the object of the experiment was to get the residual effect of the growth of the legume on the yields of corn and wheat. It is significant that the orchard grass in the rotation maintained yields better than soybeans, no doubt largely because the grass prevented the leaching of nitrates from the soil. It is highly probable that less manure would be required to maintain a given level of productiveness in a clover rotation than in a soybean rotation. The cost of producing soybean hay is much greater than for clover hay where clover grows well. The use of cover crops is also necessary when soybeans are grown in rotation, and adds to the cost, while not so effectively preventing leaching as grass already established.

If Kentucky adapted strains of clover had been used, it is probable that the clover failures would have been fewer or that there would have been none, except for the seeding of 1930 which failed on account of the severe drouth. These strains had not been tested sufficiently to establish their merit until the last two or three years of this experiment.

Rotations 4 and 5 are the same except for the order of the crops. Corn was decidedly better following soybeans than following wheat, while wheat was but little better following soybeans than following corn. The soybeans yielded less where they followed corn. These results indicate that the order of crops in Rotation No. 4 is better than that in No. 5, when the effect on all crops is taken into consideration.

The yields of wheat in the tobacco rotation merely confirm what is known by all tobacco growers, namely, that tobacco is a highly favorable preceding crop for wheat.

Rotations 5 and 6 are alike except that the beans were planted in 28-inch rows to 1927, inclusive, in Rotation No. 5, while they were drilled solid in Rotation No. 6 thruout the experiment. During the period 1921-27, average yields of hay in the two rotations were almost identical. Beginning with 1928, the beans were drilled solid in Rotation No. 5. Beginning with the same year, the beans in Rotation No. 6 were threshed and the straw was returned for the next year's corn crop. The average yield of corn from 1921 to 1926 was 2 bushels greater

in No. 6, but in 1927 and 1928 the yield of corn was 7 bushels more to the acre than in Rotation No. 5. The wheat yields in the two rotations were almost identical. The two methods of seeding beans were introduced into the rotation because previous observations had led to the belief that the yields of wheat might be affected by the different methods. It is possible that where soybeans were drilled solid there may have been a larger and better distributed nitrogen fixation which affected the corn more than the wheat.

The changes in the nitrogen content during the ten-year period are in fair agreement with changes in crop yields except for Rotation No. 6, in which the nitrogen gain for surface and subsoil combined is greater than in Rotation No. 7. However, the nitrogen gain in the surface soil is much greater in No. 7 than in No. 6. The nitrogen figures for Rotations No. 1 and No. 7 are not consistent, since the rotations are duplicates. Number 1 lies at the lower end of a slight slope, and No. 7 at the upper end.

MANURING EXPERIMENTS

In 1920 a manuring experiment was begun in a rotation of corn, wheat and clover to determine (1) the most economical amount of manure to use, and (2) the relative benefits of manure when applied to the different crops in the rotation. The cropping of the land for a few years previous to its use for this experiment was as follows:

- 1908-10. Timothy.
- 1911. Corn. Land dressed with soybean straw.
- 1912. Oats.
- 1913-15. Alfalfa.
- 1916-17. Corn, manured, 12 tons per acre in 1917.
- 1918. Oats.
- 1919. Wheat. Seeded to clover.

The land was limed in 1913, before sowing to alfalfa, except a strip of uniform width thru the field. A large part of Series 200 of the manuring experiment was on this strip, each plot containing the same amount of limed and unlimed land. Because of the poor growth of clover on the unlimed land, it

was limed in 1927, except a strip 20 feet wide, left for observation of the effects of lime.

The corn crop of 1920 was grown on land that had a good stand of clover turned under from a seeding of 1919, while the crop of 1921 followed a harvested clover crop from the same seeding.

Corn failed in 1930 on account of drouth. Wheat failed in 1924 and 1928 on account of winterkilling.

Soybeans were used for hay in 1921 as a substitute for clover in starting the rotation, and in 1924, 1926 and 1928 when clover failed. Two of the failures were on limed land. Clover was almost a failure in 1930 on account of drouth and the crop of 1931 was a failure because of drouth in 1930. Korean les-pedeza was used as a substitute, but did not grow high enough to cut, altho the stand was thick. Alfalfa was mixed with clover for the crops of 1929 and 1931.

Table 10 gives the amount and method of application of manure and the crop yields from 1920 to 1931.

An examination of the yields in the manuring experiments shows that the most advantageous place in this rotation to apply manure is on corn. There was a slight but not significant advantage to the corn in applying it on the broken land rather than before breaking, while there was a slight tho not significant decline in wheat and clover where manure was applied on the broken ground as compared with applying before breaking. Where the manure was applied on the wheat, the increase in corn yields was 5 bushels per acre less than where it was applied on the sod before breaking for corn. Wheat was not affected, while for clover, the increase in yield was 366 pounds per acre more with manure applied on the wheat. Where manure was applied on the young clover, the increase in yield of corn was 4.9 bushels per acre less than where it was applied on sod for corn; the increase in wheat yield was slightly less, while for clover it was 475 pounds greater.

Soybeans grown as a substitute when clover failed were not affected by the place of the manure in the rotation except that where it was applied on the young clover the bean hay was

TABLE 10. CROP YIELDS PER ACRE, MANURING EXPERIMENT.

Plot No.	Manure		Corn, Bus.				Wheat, Bus.				Clover Hay Lbs.		Soybean Hay Lbs.	
	Tons Per Acre	Place of Application	Average 11 Crops	Increase*	Average 8 Crops	Increase*	Average 9 Crops	Increase	Average 6 Crops	Increase	Average 6 Crops	Increase	Average 3 Crops	Increase
1	None	On clover sod before breaking	51.6	—	55.2	—	25.3	—	27.3	—	3217	—	4761	—
2	4		60.1	9.0	65.3	10.7	27.9	2.6	29.1	1.8	3596	379	4867	106
3	6		59.0	8.4	64.4	10.5	27.7	2.7	29.0	2.7	3721	509	4935	296
4	8		59.8	9.7	65.5	12.3	28.2	3.5	29.2	4.0	3615	409	4965	448
5	None		49.6	—	52.6	—	24.7	—	25.2	—	3206	—	4517	—
6	10		62.5	12.3	69.4	16.2	29.1	4.4	30.3	5.1	3818	548	5081	564
7	4	On broken sod and disked in before corn	60.1	9.2	65.2	11.4	26.8	1.8	28.0	2.3	3270	33	4906	409
8	6		62.5	11.0	67.8	13.3	27.3	2.1	28.1	1.9	3709	441	4921	445
9	None		52.2	—	55.1	—	25.2	—	26.2	—	3268	—	4476	—
10	8		62.2	10.8	68.3	13.9	28.3	3.1	29.6	3.4	3781	513	4771	295
11	10		61.4	10.8	67.4	13.7	28.8	2.9	29.6	3.2	3793	609	4719	273
12	4	On wheat in early winter	—	—	60.4	7.4	27.8	2.3	28.5	1.9	3680	580	4589	163
13	None		49.1	—	52.3	—	25.5	—	26.6	—	3100	—	4416	—
14	6		—	—	59.6	6.2	28.6	3.1	29.5	2.9	4102	1002	4678	252
15	8		—	—	59.7	5.1	28.5	3.2	28.9	2.4	4076	811	4876	396
16	4	On yng. cl. soon after wh. har.	—	—	61.8	6.1	—	—	27.4	1.0	4292	862	4856	312
17	None		52.5	—	56.8	—	25.0	—	25.4	—	3430	—	4544	—
18	6		—	—	63.8	6.9	—	—	29.0	2.6	4198	768	5058	514
19	8		—	—	63.0	6.0	—	—	28.7	3.3	4420	1087	5340	691
20	Sw. cl. instead red		56.1	3.0	61.3	4.2	—	—	26.8	2.5	4415	1189	4710	—43
21	None		53.1	—	57.2	—	24.3	—	24.3	—	3236	—	4753	—

*The increases in yields are calculated by assuming a uniform variation in soil between check plots.

increased 225 pounds per acre. When clover failed, the failure occurred under all methods of applying the manure.

In all the foregoing comparisons of the effect of the place of applying manure, an average of all the rates of application was used as the basis of comparison.

A comparison of rates (using an average of each rate in two methods of applying for corn) shows little advantage for more than 4 tons per acre. Ten tons per acre gave an increase, over 4 tons, of 2.5 bushels of corn, 1.5 bushels of wheat, and 372 pounds of clover hay, hardly sufficient to warrant the use of the extra amount under the conditions of this experiment.

Moisture is nearly always a limiting factor in growing corn in this region. It is highly probable that where clover can be grown successfully, the residue that is left in the soil when it is cut for hay, supplemented by 4 tons of manure per acre, on corn, will maintain an economical nitrogen level after it has been brought up to a level that will produce approximately 50 bushels of corn per acre. Studies on rainfall distribution and corn yields indicate that 60 bushels is about as high an average yield of corn as can be economically maintained when a period of ten years or more is taken into consideration.

The results support the common practice of farmers in using manure at a lower rate on a larger area when it is scarce. It appears significant to the writers that the yield of corn is considerably lower where manure is used on wheat or clover, while the yield of clover is not greatly increased. It is possible that the explanation may be that when manure is applied on wheat or clover, the clover fixes less nitrogen and uses more from the manure and soil, thus leaving a deficiency for corn.

At the same time that the manuring experiments in rotation were begun, a manuring experiment was begun in continuous corn culture. The land occupied by the experiment lies between the rotation experiments and the manuring experiments in rotation, and is contiguous to both. Its previous cropping history is the same as for the land used in the rotation experiments.

Frequently farmers have stated that they would like to grow corn continuously upon the same land because of its near-

ness to the silo, or for some other reason, and have asked if high yields could be maintained by heavy manuring. This experiment was undertaken to answer that question.

In this experiment the entire crop was removed and a winter cover crop of rye was used. Manure was used at the rates of 10 tons, 12 tons and 15 tons, applied on alternate crops to 1928, inclusive. On one plot without manure cowpeas were seeded each year at the last cultivation of the corn, to 1928, inclusive. All plots were limed at the rate of 2 tons per acre in 1927. The yields are given in Table 11.

TABLE 11. YIELDS OF CORN, IN BUSHEL PER ACRE, IN CONTINUOUS CULTURE.

Plot No.	Treatment*	Year												Increase
		1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1931†	Ave.	
1	None	64.9	23.1	48.6	40.0	29.7	32.0	28.0	13.3	26.5	11.6	14.7	30.2	.....
2	Cowpeas catch crop	67.7	31.1	35.1	42.9	38.6	40.3	40.9	11.1	54.7	25.4	24.1	37.4	5.8
3	10 tons manure ..	80.6	37.1	47.3	51.7	48.9	48.6	60.9	26.4	55.4	30.6	26.5	46.7	13.7
4	None	73.1	38.6	39.4	42.9	30.3	34.3	38.0	13.2	31.9	18.8	18.1	34.4	.....
5	12 tons manure ..	70.6	34.3	37.7	46.1	43.4	40.9	52.9	30.7	55.4	24.7	25.0	42.0	8.0
6	15 tons manure ..	74.0	31.4	38.6	50.3	50.6	45.7	64.6	33.9	57.2	26.1	28.4	45.5	12.0
7	None	72.0	27.1	32.9	43.7	32.9	35.4	34.9	26.5	29.9	11.8	23.5	33.1	.....

*Manure was applied on alternate crops, beginning with first crop and continuing to 1928, inclusive.

†Corn was a failure in 1930, due to drouth.

The average yield of the check plots for the first three years, 1921-23, in the continuous culture experiments was 46.6 bushels per acre, while the yield of check plots, 1, 5, 9 and 13 in the manure-rotation experiment was 42.2, showing that the land used for the continuous culture experiment was more productive at the beginning of the two experiments. Rotation without manure has maintained a higher yield than the best manured plot (No. 3) in continuous culture, by a margin of 4

bushels per acre, as an average for 11 crops. Cowpeas seeded at the last cultivation have been about half as effective as manure in increasing yields (Compare Plot 3 with an average of Plots 3, 5 and 6).

As already indicated, no manure was used in 1930, and the corn crop for that year was a total failure for grain, due to drouth, and was harvested for silage. One-half of each plot was fertilized in the hill with 75 pounds per acre of 12-24-12 fertilizer. A rye cover crop was used as usual. In 1931 the same half of each plot was again fertilized in the hill, as in 1930. The fertilizer was applied by hand and mixed with the soil with a hoe. The corn was badly injured by drouth in early August. The yields were as follows:

Plot and Treatment	Fertilized	Unfertilized	Difference
1. None	33.4	14.7	18.7
2. Cowpeas	44.2	24.1	20.1
3. 10 tons manure	45.2	26.5	18.7
4. None	35.3	18.1	17.2
5. 12 tons manure	41.2	25.0	16.2
6. 15 tons manure	39.3	28.4	10.9
7. None	28.4	23.5	4.9
Ave. Plots 3, 5, 6	41.9	26.6	15.3
Ave. Plots 1, 4, 7	32.4	18.8	13.6
Residual effect of manure	9.5	7.8	

The average yield of Check Plots, 1, 5, 9 and 13 in the manure-rotation experiment was 49.2 bushels in 1931.

TESTS OF FERTILIZERS FOR TOBACCO

In 1917 a test of fertilizers for tobacco was begun on the Experiment Station farm, on land that had been used since 1908 for a six-year rotation consisting of tobacco two years, wheat, clover and bluegrass for three years. The tobacco crops prior to 1917 consisted of variety tests without fertilization. The cropping history of the land prior to 1908 is not known. The same rotation was used in the fertilizer test, beginning on a blue grass sod. All crops were removed, including the bluegrass when it made enough growth to cut.

Fertilizing materials, where used, were applied at the following rates for each tobacco crop:

Nitrate of soda	200 lbs. per acre
Sulphate of potash or its potash equivalent in other forms.....	100 lbs. per acre
Superphosphate (16 percent)	200 lbs. per acre
Cottonseed meal, nitrogen equivalent of 200 lbs. of nitrate of soda	
Manure	10 tons per acre

Limestone was used at the rate of 2 tons per acre on the first of the two tobacco crops, on Plots 8, for two rounds of the rotation which made a total of 4 tons per acre for the set of limed plots.

Only four different fertilizer tests were included for the first three years. Other tests were added in 1920. The fertilizers were applied in the row and mixed with the soil by disk-ing, except for the second and third years, when part of the fertilizer was applied broadcast and a part along the rows after setting.

A root-rot resistant strain of tobacco was used, beginning with 1924.

The fertilizer treatments used and the average yields per acre are given in Table 12.

Under the conditions of this experiment, nitrogen was the most important element in the fertilizer in increasing yield; potassium was next; while phosphorus did not increase the yield, as would be expected on a high-phosphorus soil. Limestone apparently caused some decrease in the yield, and the quality has been distinctly inferior in some years. Ten tons of manure on each tobacco crop was not so effective as 200 pounds of nitrate of soda. Cotton seed meal was not nearly so effective as nitrate of soda.

The effect of fertilizer on the quality of tobacco was not significant. No detrimental effect was apparent. In some years there was some evidence of slight improvement in quality due to fertilizers. (For recommendations for fertilizing tobacco, see pages 262-265.)

TABLE 12. AVERAGE ANNUAL YIELDS OF TOBACCO PER ACRE IN FERTILIZER TESTS, EXPERIMENT STATION FARM, LEXINGTON.

Plot No.	Treatment*	1917-29 Pounds	Increase Due to Fertilizers	1920-29 Pounds	Increase Due to Fertilizers
1	O	1348	-----	1264	-----
2	N	1528	174	1467	205
3	O	1360	-----	1259	-----
4	KN	1571	239	1481	244
5	O	1304	-----	1214	-----
6	PKN	1560	243	1447	216
7	O	1329	-----	1247	-----
8	LPKN	1533	199	1411	167
9	O	1338	-----	1240	-----
10	K	-----	-----	1290	53
11	O	-----	-----	1233	-----
12	PN	-----	-----	1375	124
13	O	-----	-----	1269	-----
14	M	-----	-----	1417	133
15	O	-----	-----	1298	-----
16	CS	-----	-----	1393	75
17	O	-----	-----	1338	-----

*O = no treatment; N = nitrate of soda; K = potash; P = superphosphate; L = limestone; M = manure; CS = cottonseed meal.

MISCELLANEOUS TESTS IN THE APPLICATION OF FERTILIZERS AND LIME

Placement of Fertilizers for Corn. For four years the Experiment Station has cooperated with several other experiment stations, the American Society of Agronomy, the National Association of Farm Equipment Manufacturers, the American Society of Agricultural Engineers, and the National Fertilizer Association in making tests to determine the best placement of fertilizers for corn. Results have been obtained on three crops, the crop of 1930 having failed because of drouth.

The experiments were conducted on land at Lexington recently acquired by the Experiment Station. This soil has a

phosphorus content of approximately 2100 pounds of phosphorus in 2,000,000 pounds of soil, which is very much lower than the soils on which the other experiments in this report were made. So far as can be determined, no fertilizers had ever been used on this land, and very little manure had been used. The average yield of corn for the check plots in the experiments were 56, 27 and 72 bushels per acre, for the three years, the highest yield following a good sod manured at 7 to 8 tons per acre. The average for three years was 52 bushels per acre.

In these tests 125 pounds of 4-10-6 fertilizer per acre, in the hill, increased the yield an average of 14.3 bushels per acre, for the three years, while 500 pounds applied broadcast increased the yield 10.1 bushels. The fertilizers were carefully hand-placed in the hill in various positions with reference to the seed. In two of the years tests were made with machine application of fertilizer in comparison with the careful hand application. An attachment to the planter was used which was designed to split the hill application and place it in bands on opposite sides of the seed. For these two years the hand application produced about twice the increase that the machine application produced.

There seems little doubt that hill application of fertilizers for corn is better than broadcasting, especially when complete fertilizers are needed which are used at a low rate per acre. Where the soil is being systematically fertilized with mineral fertilizers (phosphate fertilizer or potash fertilizer or both) drilled in with grain and followed by legumes, and where the farm manure is being saved and used, hill fertilization of corn may not be expected to give such large increases in yields as in these tests or to be so greatly superior to broadcast applications.

In one test in 1929, on soil well managed for many years by the use of a good rotation and manure, the yield of corn was not materially affected by the use of complete fertilizers in the hill, while in another test, on soil that had been poorly managed, the yields were 26 bushels without fertilization and 48 bushels with hill fertilization.

The results of the placement tests seem to indicate that for this region the most effective practical placement of fertilizers in the hill is in parallel bands on opposite sides of the seed and a little below the level of the seed.

Soluble Nitrogen Fertilizers in Water for Transplanting Tobacco. Many tobacco growers have requested information on the use of nitrate of soda or other soluble nitrogen fertilizers in water used in transplanting tobacco. For the purpose of obtaining definite information on the practice, tests were made in 1929 and 1930. In the 1929 test, nitrate of soda, calcium nitrate and ammonium nitrate were used at the following rates:

1	pound of nitrate of soda in 50 gallons of water.
2	pounds Do
4	pounds Do
6	pounds Do
8	pounds Do
10	pounds Do
3	pounds calcium nitrate in 50 gallons of water.
5	pounds Do
1½	pounds ammonium nitrate in 50 gallons of water.
3	pounds Do

Frequent check plots were used which were watered with one-fourth pint of water per plant. Each of the solutions was used at the rates of one-fourth pint and one-half pint per plant. One pound in 50 gallons of water equals 5.2 pounds per acre when one-fourth pint per plant is used on plants spaced 18 inches apart in rows 3.5 feet apart. One-fourth pint per plant requires 260 gallons of water per acre.

One set of these tests was made on tobacco transplanted when the soil was quite dry, and the other after a rain when the soil had just passed out of condition for setting without water. In the first test, set on June 4, concentrations of nitrate of soda of 6 pounds or more to 50 gallons of water caused wilting, on June 7, in comparison with the check plots. Calcium nitrate and ammonium nitrate caused some wilting. No marked injury was apparent at this time. A heavy rain occurred on June 9. By June 13, plants watered with all concentrations had re-

covered without any apparent injury. Later observations showed no consistent differences in any of the plots.

The second test plots were set on June 11, following a heavy rain on June 9. In this test all concentrations of all materials produced wilting in excess of check plots. By June 25 all tests showed almost complete recovery, and recovery was complete on July 1. Later observations showed no consistent differences in the plants of the various tests.

In addition to these tests, a solution of 5 pounds of urea to 50 gallons of water was used in the first set of tests. It produced permanent injury. In the second set of tests, a solution of 5 pounds of ammonium sulfate in 50 gallons of water was used. It produced permanent injury.

No improved growth resulted from any of the treatments. The soil was fertile.

In 1930 similar tests were made with solutions of nitrate of soda of 4 pounds, 8 pounds and 12 pounds in 50 gallons of water, and used at the same rates per plant as in the tests of the preceding year. The tobacco was set June 12. The season was dry. The solutions stronger than 4 pounds to 50 gallons of water caused serious injury thruout the season, many plants being killed. Where one-half pint of the 4-pound solution was used, there was considerable injury.

Our conclusion is that the use of nitrate of soda, or other soluble salts, in water for setting tobacco, in sufficient quantities to have fertilizing value, is inadvisable because of the danger of injury to plants, and that the amount of injury is affected by moisture conditions which are, of course, not predictable. If fertilizers are needed, it is best to apply them in the row and mix them thoroly with the soil.

Fertilizer Placement Tests with Tobacco. In 1930, tests were made on various, placements of fertilizer for tobacco. A 6-8-6 fertilizer was used (except Plot 11), in which the nitrogen was derived from equal parts of nitrate of soda and sulfate of ammonia—that is, 16.6 pounds of each in each hundred pounds of fertilizer. The fertilizer was used at the rate of 500 pounds per acre. Each test was made four times, on 1/300-acre plots.

The season of 1930 was very dry at setting time (June 12) and continued so until August, when light rains occurred, after which the tobacco made very rapid growth. The plan of the experiment and the average yields of the four series were as follows:

Plot No.	Placement of the Fertilizer	Yield Pounds per Acre
1.	No fertilizer	1,395
2.	In strip 4 inches wide, worked into soil 3 to 4 inches.....	1,594
3.	In strip 8 inches wide, worked into soil 3 to 4 inches.....	1,594
4.	No fertilizer	1,313
5.	In strip 12 inches wide, worked into soil 3 to 4 inches.....	1,688
6.	In bottom of marker furrow, split as with setter shoe. Set tobacco in split	1,463
7.	No fertilizer	1,313
8.	In two parallel narrow bands 4 to 5 inches apart and 3 inches deep; tobacco between	1,463
9.	On top of soil; soil ridged over it. Split ridge as with setter shoe. Set tobacco in split	1,406
10.	No fertilizer	1,500
11.	250 pounds per acre of 12-24-12, placed as in No. 6.....	1,500
12.*	No fertilizer	1,395

*Plot 12 was counted as Plot 1 of the next series; that is, Plot 12 is the end of one series and the beginning of the next.

The test was repeated in 1931. The soil was quite dry when the tobacco was set June 27 with excellent plants, watered liberally. The tobacco made poor growth and yields were not taken. The following stands were found on July 16, stated as the average of each group of four plots.

Plot	Average No. Plants per Plot*
Plot 1 check	27 $\frac{1}{4}$
2	20 $\frac{1}{2}$
3	16
4 check	24 $\frac{3}{4}$
5	24 $\frac{3}{4}$
6	10 $\frac{1}{4}$
7 check	19 $\frac{1}{4}$
8	12 $\frac{1}{2}$
9	18 $\frac{3}{4}$
10 check	23
11	18
12 check	21 $\frac{3}{4}$

*Thirty-five plants per plot is a perfect stand.

While there is a lack of consistency in the results for 1931, they tend to show that the more the fertilizer is concentrated about the plant, the greater the injury. They also show that season has a decided effect on the injury from fertilizers.

Rates of Fertilizer Applications in the Row, for Tobacco.

In 1930 and 1931 tests were made to determine what amount of fertilizer could be placed in the row, for tobacco, without injury. The same fertilizer was used as in the placement tests (see page 251). The ground was marked off for tobacco with a "sled runner" marker, which left a furrow about 3 inches deep and 3 inches wide. The fertilizer was spread on the sides and the bottom of the furrow, then the tobacco was set with a tobacco setter, the shoe of which mixed the fertilizer with the soil to some extent. This method of application is approximately the same as that of the fertilizer attachment on most tobacco transplanters, which drop the fertilizer in the furrow ahead of the shoe. Plots of a single row 25 feet long were used (1/500 of an acre). Following are the rates of application and the average yield of four tests of each rate, in 1930.

Plot No.	Rate of Fertilizer per Acre	Lbs. per Acre
1	0	1,468
2	400	1,500
3	600	1,625
4	800	1,687
5	1,000	1,625
6	1,200	1,562
7	1,400	1,594
8	1,600	1,625
9	1,800	1,812
10	2,000	1,718

There was no consistent relation between the number of plants injured and the rate of application of fertilizers. However, the injury to the fertilized tobacco was greater than to the unfertilized, and the injury tended to increase with more than 1200 pounds per acre, being greatest on Plots 9 and 10. The

injury was not great for any rate. The tobacco was set at the same time as that for the placement tests. It should be remembered that this was the severe drouth season of 1930.

Along with this test was a single-series test of a concentrated synthetic fertilizer of the analysis 12-24-12, used at the rates of 200, 300, 400 and 500 pounds per acre. The yields were 1375, 1375, 1500 and 1500 pounds, respectively. There was somewhat less injury than with the other fertilizer. The same test was made in 1931. The tobacco was set at the same time as in the placement tests of that year (see page 251), each test being repeated five times. Every rate of application greatly injured the plants this year. The stand on the check plots was 80 percent, 30 percent with the 400-pound rate, and ran down to 2.5 percent with the 2000-pound rate. These results indicate that thoro mixing of the fertilizers with the soil in the row is highly essential and that seasonal conditions have a large influence on the amount of injury. This work will be continued because fertilizer placement is evidently an important consideration.

Drilling Lime with Small Grain. Since 1923 the Department of Agronomy has been recommending the trial by farmers of a mixture of superphosphate with a small amount of limestone or burned lime drilled with small grain to be followed by clover. The ratio recommended was two or three parts of lime to one part of superphosphate. The trial tests were effective and the practice is largely used in many regions of the state.

The question arose as to the danger of injury to germination of small grain when quicklime or hydrated lime is used. In 1927 a test was made to obtain information on this point. Duplicate tests were made with quicklime applied at the rates of 500 pounds, 750 pounds and 1000 pounds, both alone and in mixture with half of its weight of superphosphate. A single test each of 1500 pounds and 2000 pounds per acre was made. The work was done by hand, in 10-foot rows. Furrows were opened as near the size of a drill furrow as could be estimated. The lime or mixture was placed in the bottom of the furrow. Wheat testing 80 percent germination was then sown in the furrows at an average rate of 180 kernels to 10 feet of row. A pointed stick

was dragged along the furrow to mix the lime, fertilizer and seed. The seed was then covered about $1\frac{1}{2}$ inches deep. The seeding was done in the forenoon of April 29. Rainfall following the seeding was as follows:

April 29	.....	.43 inches
30	.....	.36 inches
May 3	.....	.11 inches
4	.....	.25 inches
5	.....	.07 inches
6	.....	.01 inches
8	.....	1.03 inches
10	.....	.14 inches

On May 11 a count was made of the stand, with the following results:

Average of checks	.....	113 plants
Average with 500 lbs. lime per acre	.....	126 plants
Average with 750 lbs lime per acre	.....	98 plants
Acreage with 1,000 lbs. lime per acre	.....	119 plants
Average with 500 lbs. lime +250 lbs. superphosphate	....	116 plants
Average with 750 lbs. lime +375 lbs. superphosphate	....	109 plants
Average with 1,000 lbs. lime +500 lbs. superphosphate	....	120 plants
With 1,500 lbs. lime	.....	90 plants
With 2,000 lbs lime	.....	82 plants

In 1928 a test was made in the greenhouse under two different moisture conditions. Field soil was used on greenhouse benches and was brought to moisture content of 16 percent, about the minimum for growth. Furrows were opened across the bench, in which selected grains of wheat were spaced $\frac{3}{4}$ inch apart (43 grains per row). In one section, quicklime was placed uniformly over the kernels in a strip $\frac{3}{4}$ inch wide, at the rates of 500, 750, and 1000 pounds per acre, and again at the same rates mixed with one-half the weights of superphosphate. After this was done, the furrows were filled with soil. This section was kept at about the same moisture content as at planting time. A second section was treated and planted in exactly the same way, but after covering, the soil was brought practically to saturation, without producing underdrainage.

The plantings were made on January 24. On January 30, no plants had appeared in Section 1 (dry). In Section 2 (wet), plants from 40 of the 43 grains were thru the soil in the check rows. By February 9, plants from practically all grains were thru. In Section 1, maximum emergence was practically reached on February 14. The final counts were made on February 24. In the dry section the stand was 40 with 500 pounds of lime per acre, and 41 with 750 pounds of lime and 375 pounds of superphosphate. With the 1000-pound rate of lime, the stand was 32 both with and without the phosphate. In the wet section the stand was 37 and 35 with 500 pounds of lime, alone and in mixture, and 28 and 24 with the 1000-pound rate. The 750-pound rate of lime gave an intermediate stand. The stand on the check rows was 42 for the dry section and 41 for the wet section, out of a possible 43.

As stated, the lime was placed over the seed without mixing with the soil. After the test was finished, examination showed the failure of many plants to emerge, with the heavier applications, was because of the hardening of the lime over them to such an extent that they could not penetrate it. Very few were killed.

In 1928 a test was made in which builders' hydrated lime was drilled in with oats at the maximum capacity of the fertilizer attachment of the grain drill, which was 425 pounds per acre. The seeding was made on April 13. Extensive counts of stand were made on May 5. There was no injury whatever to the stand and at no time was there any evidence of retarded germination.

In the fall of 1928, builders' hydrated lime and superphosphate were drilled with wheat, both alone and mixed with superphosphate, in the ratio of 2 parts of lime to one of superphosphate. Counts of stand were made in twenty five-foot sections of drill row, distributed over the various plots. The results of the counts were as follows:

Check plot	896 plants
400 lbs. superphosphate	1,002 plants
600 lbs. superphosphate	909 plants
640 lbs. mixture	952 plants
400 lbs. mixture	1,023 plants
580 lbs. hydrated lime	1,022 plants

It seems safe to conclude from these results that any amount of quicklime or hydrated lime that can be delivered thru the fertilizer attachment of a grain drill will not injure the germination and early growth of small grains. However, it is advised that those who contemplate using burned lime in this way try it first on a small scale.

Tests in progress at the Princeton substation show that small applications of limestone or hydrated lime, applied when small grain is seeded, are very effective on the legume crop seeded on the grain.

RECOMMENDATIONS ON SOIL MANAGEMENT AND FERTILIZER PRACTICES

There is a wide variation in the soils of the Bluegrass Region of Kentucky. The most important of these variations that affect soil management and fertilizer practices are the lime and phosphorus content of the soil. Some soils contain sufficient of both, others of only one, while some are deficient in both. With these deficiencies supplied, the same soil management practices are applicable to all the soils of the region, except a few small areas of poor drainage which may be relieved by open ditch or tile drainage.

1. *Rotations.* A rotation of crops should include one legume crop in a two- to four-year rotation of harvested crops. If the rotation is made longer by adding grass, either for hay or pasture, a legume should be included in mixture with the grass. The choice of the legume depends in part upon the adaptability of the soil to different legumes, and partly upon the use to be made of the crop. For hay, seeding a mixture of two or more legumes and a small amount of grass is good practice. Red clover, alfalfa and timothy make a good hay mixture where these legumes will grow. Lespedeza is valuable in most mixtures when a more or less temporary pasture is desired following the hay crop. If clover and alfalfa will not grow, lespedeza may be mixed with grass for hay and may give a hay crop after the grass is cut.

To prevent erosion and leaching, land should be occupied by growing crops as much of the time as possible. The rotation should be planned not only to accomplish this, but to reduce plowing and the seeding of special cover crops to a minimum. Keeping land in grass is the best means of preventing both erosion and leaching. It is self-evident that the more productive the crop land is kept, the smaller the area needed for harvested crops and the larger the proportion of the farm that can be kept in grass. The effects of erosion and leaching in reducing the productivity of soil are many times as great as the removal of plant food in harvested crops.

2. *Use of Legumes and Manure.* None of the legumes will greatly increase the nitrogen content of medium to good soil unless they are pastured, left on the ground or fed and the manure made by feeding them returned to the soil. Where soybeans and cowpeas are removed from the soil, without return of manure, the nitrogen content of the soil may be lowered because of the relatively small root systems of these plants and the leaching which takes place before a cover crop can be grown large enough to prevent it (See Rotation Experiments, page 236). If the manure made from feeding them is fully saved and returned, more nitrogen may be added to the soil than is withdrawn. Cowpeas and soybeans are expensive crops because of the labor involved in preparing the ground and seeding, the cost of the seed and the cost of the necessary cover crop when they are grown, or the loss from leaching if a cover crop is not used. The extra labor and expense ordinarily involved in growing a crop of cowpeas or soybeans often will be equal to the cost of liming the soil sufficiently to produce clover for eight to ten years. Soybeans and cowpeas are excellent emergency crops, but are inferior to clover, alfalfa and lespedeza in maintaining the nitrogen supply of the soil. Pasture mixtures must also contain legumes if sufficient nitrogen is to be maintained to meet the needs of the grass without using commercial nitrogen.

Manure should be as carefully saved as practical livestock management permits. The amount of manure that can be saved depends upon the methods of feeding, pasturing and housing.

If all feeding is done under cover, sufficient bedding used, and animals are kept under cover when pastures should not be used, it is not difficult to save a ton of manure for each ton of feed and bedding used. One and one half tons of manure for each ton of feed and bedding used is possible when all excrement is saved and sufficient bedding is used to absorb the urine. A large part of the nitrogen and potash of feeds is recovered in the excrement of animals, a large part of the recovery being in the urine; hence the importance of bedding and the protection of the manure from leaching. The purchase of commercial nitrogen and potash can be reduced greatly by conservation and use of manure. Deficiency of potash and other mineral fertilizers may be greatly hastened by the growing of legumes if manure made by feeding them is not returned. This is particularly true of alfalfa. (See pages 242 and 244 for rates and place in the rotation to use manure.)

3. *Use of Liming Materials.* A large proportion of the soils of the Bluegrass Region need liming to produce good crops of clover. On most of them liming is a necessity for alfalfa. Exceptions are found in the hilly parts of the Bluegrass Region and in some other places where there is considerable loose limestone rock in or near the surface soil. On some of the more acid soils, yields of the so-called acid-tolerant legumes—soybeans, cowpeas and lespedeza—may be considerably increased by liming. One or two tons of ground limestone or the equivalent in burned lime usually is a sufficient initial application. However, a minimum of two tons is recommended for alfalfa. It has been found that lime is more effective for alfalfa, if it has been applied some time before sowing the alfalfa. It is a good plan to apply it when preparing for the crop preceding alfalfa. However, lime usually should not be applied immediately before a tobacco crop.

Reliming should be done only when there is evidence of the need for it. On most soils, two tons per acre of limestone or its equivalent will be effective for eight to ten years, or even longer, if good management is practiced. The need for reliming may be tested by reliming a small area preceding a legume crop and noting the effect.

On land on which tobacco is to be grown, only moderate applications of a liming material should be used, and it should be applied as far in advance of the tobacco crop as possible. There is no evidence in any of the experimental work of the Experiment Station that liming directly benefits tobacco; in fact there is evidence of lowering of yields and of injury to quality by liming too heavily. Two tons per acre immediately preceding the crop has produced injury. There is, however, evidence of much improvement from liming thru its effect on legumes in the rotation. This experience should not deter farmers from using liming materials on tobacco land, but they should be careful as to the amount used and the time of using it. Where too much lime has been used its injurious effects on tobacco may be overcome to some extent by liberal fertilization with high-grade complete fertilizer.

Where liming materials are expensive on account of long haul or other causes, it is recommended that ground limestone or hydrated lime be drilled in with small grain at the maximum capacity of the drill. This should greatly benefit the clover and grass mixtures sown on the small grain. It should first be tried on a small scale. The practice is giving excellent results in many parts of the state. It is especially recommended on land on which tobacco is to be grown. It will be necessary to repeat the treatment before each legume crop for a few years. The plan has the merit of enabling the farmer to grow legumes on a large area with a small outlay for liming materials. If the soil is deficient in phosphorus (See use of phosphate fertilizer, next section, No. 4) the lime may be mixed with superphosphate, or mixed fertilizer containing a liberal amount of phosphorus, in the ratio of 2 to 1 and drilled with grain as suggested. However, quicklime and hydrated lime should not be mixed with fertilizers containing ammonium salts.

Many county agents are prepared to test soils for lime and phosphorus needs and are glad to render the service.

4. *The Need for Phosphate Fertilizers in the Bluegrass Region.* Altho there are many soils in the Central Bluegrass Region that contain so much phosphorus that phosphate fertilizers produce no effect, there are many that are deficient in

phosphorus; they may occur near areas of soils that are very high in phosphorus. When the phosphorus content is as low as 2,000 pounds in 2,000,000 pounds of soil (an acre to the depth of about 7 inches), crops will in all probability respond to phosphate fertilizers unless the soil has been unusually well managed thru growing legumes and the use of manure. There are chemical tests that give a fair indication of the need of phosphorus in these border-line cases, but the best test is a field test that may be made by the farmer. The following plan is offered for making a test for the need of both lime and phosphate fertilizer, on 1/4 acre plots. (Plots 181.5 feet long and 60 feet wide contain one-fourth acre.)

No lime or phosphate	Limestone ½ ton	Superphosphate 125 lbs.	Limestone ½ ton Superphosphate 125 lbs.
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The limestone (or lime) and superphosphate should be applied broadcast on the broken ground and disked in, followed by grain on which a mixture of clover and alfalfa (inoculated) may be sown. The applications may be made on corn ground, followed by wheat or rye on which the clover or alfalfa is to be sown. Oats may be seeded immediately following application in the spring. Careful observation of the various crops will give valuable information as to the need for both materials.

If it is found that phosphate fertilizer produces decided effects, it should be used systematically. It is suggested that 500 to 400 pounds of superphosphate per acre, or its equivalent of other phosphate fertilizers, be used with the small-grain crop on which will be sown a legume and grass mixture of the character desired for hay or pasture.

5. *The Use of Complete Fertilizers for Grain Crops.* If the soil is naturally well supplied with phosphorus, a rotation with sufficient legumes in it has been used regularly, and a fair amount of manure is returned to the soil, it is not likely that

fertilizers will be profitable on any field crops except tobacco and perhaps alfalfa. (See results of Lexington soil experiment field, page 221, and Renewed Experiments, Series C, page 230.) If, however, the soil is low in phosphorus, and especially if it has not been well managed, it is likely that a hill application of a complete fertilizer will be profitable on corn. The following trial is suggested: Apply in the hill 125 to 150 pounds of a complete fertilizer, such as a 4-8-4, a 3-8-6, or approximately these analyses, and observe its effect. On Bluegrass soils, on land that will produce less than 50 bushels per acre in a good season the fertilizer will probably give a profitable increase.

A complete fertilizer generally gives corn a better early growth than a phosphate fertilizer, but unless the soil is moderately fertile this advantage may not be maintained. A complete fertilizer is more apt to be profitable on fairly good land than on either poor or very productive soil. The same comparison of fertilizers may be tried on small grain and the clover and grass sown with it, using 300 to 400 pounds of fertilizer an acre. Moderate applications of fertilizers, say up to 250 pounds per acre of the ordinary kinds, are generally more effective in the hill or row than broadcast. In hill applications the fertilizer should not come in contact with the seed.

It should be kept in mind that the small amount of complete fertilizer commonly used in the hill or row for corn and small grain furnishes only a small part of the needs of the crop for nitrogen and potash and that, at present prices of crops and fertilizers, the main supply of these elements is best maintained by the production and proper use of legumes and manure. However, the complete fertilizer properly used as a "starter" may be profitable under the conditions already mentioned.

6. *Fertilizers for Tobacco.* Very few soils are so fertile that it will not be profitable to fertilize tobacco grown on them, at average prices for tobacco and fertilizers. Thru a period of thirteen years it has been found profitable to fertilize tobacco on the Experiment Station farm on soil that has given an average yield of leaf of a little more than 1300 pounds an acre without fertilizer.

If it is positively known that a soil is very high in phosphorus, this element may be left out of the fertilizer and a mixture containing nitrogen and potash used. A mixture of 200 pounds of nitrate of soda, or 150 pounds of sulfate of ammonia, with 75 pounds of sulfate or muriate of potash makes a satisfactory application for tobacco on such soils. However, unless one is sure of a high phosphorus content of the soil, it is safer to use a complete fertilizer. Phosphoric acid is the least expensive part of a fertilizer and its cost is small in comparison with the value of the tobacco. The superphosphate in 500 pounds of the average tobacco fertilizer costs about \$2.50.

As a general recommendation for White Burley tobacco in the Bluegrass Region, a complete fertilizer of approximately a 1-2-1 ratio is suggested, with a minimum of 4 percent of nitrogen and potash. Some analyses of this ratio are 4-8-4, 6-12-6, 12-24-12, etc. It is not necessary that the proportions conform exactly to these figures. If tobacco is grown on soil that is not in a high state of productivity, the potash and nitrogen may both be increased. A 6-8-6 or 6-10-6 analysis would be satisfactory. Where it is believed that the soil is well supplied with nitrogen, such as a good clover sod, a fertilizer lower in nitrogen may be used, and if the early growth of the tobacco is not satisfactory, a side-dressing of soluble nitrogen fertilizer may be applied.

"Muriate of potash" may be used for tobacco in applications as high as 50 pounds of the salt per acre, with little if any danger to the quality of the tobacco. (The amount of muriate or sulfate of potash used to furnish the "potash" (K_2O) is approximately double the figure for potash. For example, 600 pounds of 4-8-4 fertilizer with the potash from muriate would contain approximately 50 pounds of muriate of potash.) Where heavier applications of potash are used, part or all of it should be in the sulfate form.

Fertilizers are more effective when applied in the row or hill. As much as 500 or 600 pounds per acre of 4-8-4 analysis or equivalent may be applied in the row if well mixed with the soil. The best method of application is the use of a fertilizer attachment that places the fertilizer in bands on each side of

the row, fairly well down in the soil. A corn planter may be used, running twice in each row so as to better mix the fertilizer with the soil. For 300 to 400 pounds per acre, the ground may be marked with a "sled runner" marker, and the fertilizer placed in the furrow with an attachment that drops the fertilizer ahead of the planter shoe. With large applications of a concentrated fertilizer, there is some danger of injury in some seasons unless the fertilizer is very thoroly mixed with the soil.

The amount of fertilizer to use on tobacco probably can best be judged by the estimated productivity of the soil in terms of corn yields. For soil that produces 30 to 40 bushels of corn per acre in a good season, 500 to 600 pounds of 4-8-4 analysis, or equivalent, is recommended; for soil that makes 50 to 60 bushels, 400 to 500 pounds. If fertilizers of higher analysis are used, the amount should be reduced proportionately.

Ten to 12 tons of manure on a high-phosphorus soil in a fair state of cultivation may be expected to give good results. If the soil is low in phosphorus, manure should be reinforced with a liberal application of a phosphate fertilizer. If only 5 or 6 tons of manure are used, an application of a complete fertilizer usually will prove profitable.

Tobacco should be grown only on well-drained soil kept productive by the use of legumes, grass, and manure.

7. *Fertilizing Alfalfa.* Alfalfa has responded to fertilizers on the Experiment Station farm where other crops, except tobacco, have failed to respond appreciably. This is particularly true for potash. Alfalfa is not only a heavy feeder on potash, but requires a large amount in a short period of growth, and unless the land is liberally manured or potash fertilizer is used a deficiency of this element is very apt to occur. In all seedings of alfalfa it is recommended that a test be made for the need of potash and phosphate. This may be done by treating a small plot, say one-fourth acre, with muriate of potash at the rate of 200 pounds per acre, another with superphosphate at the rate of 400 pounds per acre, and another plot with both. If a beneficial effect is observed from either fertilizer or both, the remainder of the field may be top-dressed accordingly. A better plan is to make a preliminary test before the time it is

intended to seed the crop. It is well to repeat that the soil in the Bluegrass Region is so irregular in character that these tests are the farmer's best guide.

When alfalfa is sown for the first time on soil that is deficient in nitrogen, a medium application of a soluble nitrogen fertilizer may be helpful in supporting the crop until inoculation becomes effective. An application supplying 15 to 20 pounds of nitrogen per acre is suggested in connection with other fertilizers.

8. *Top-dressing.* Top-dressing with soluble nitrogen fertilizers is profitable under some conditions on small grain, timothy for hay, bluegrass and orchard grass for seed and pasture. The prices of crops and fertilizer materials will determine the profitableness of the practice. The use of nitrogen top-dressing is most likely to be profitable in backward springs and on thin land, but is not likely to be profitable except on land well supplied with phosphorus and potassium, either naturally or by application.

